Ch. 4

RF POWER AMPLIFIERS

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RF POWER AMPLIFIERS

A Radio Frequency (RF) power amplifier is a type of electronic amplifier used to convert a low-power radio-frequency signal into a larger signal of significant power, typically for driving the antenna of a transmitter.

The basic applications of the RF power amplifier include driving to another high power source, driving a transmitting antenna and exciting microwave cavity resonators. Among these applications, driving transmitter antennas is most well known. The transmitter–receivers are used not only for voice and data communication but also for weather sensing (in the form of a RADAR).

RF Power Amplifiers are used in a wide variety of applications including Wireless Communication, TV transmissions, Radar, and RF heating.

RF POWER AMPLIFIERS

The basic techniques for RF power amplification can use classes as A, B, C, D, E, and F, for frequencies ranging from VLF (Very Low Frequency) through Microwave Frequencies.

RF Output Power can range from a few mW to MW, depend by application.

The most important parameters that define an RF power amplifier are:

- Gain
- Linearity
- Efficiency
- Stability
- Ruggedness
- Output Power
- DC Supply Voltage

RF POWER AMPLIFIERS

The power class of the amplification determines the type of bias applied to an RF power transistor.

The power amplifier's efficiency is a measure of its ability to convert the DC power of the supply into the signal power delivered to the load.

The definition of the efficiency can be represented in an equation form as:

$$\eta = \frac{Signal\ power\ delivered\ to\ load}{DC\ power\ supplied\ to\ output\ circuit}$$

or Power Added Efficiency: $$P_{AE} = \frac{P_o - P_i}{P_{DC}}$$

RF POWER AMPLIFIERS

Power that is not converted to useful signal is dissipated as heat. Power amplifiers that have low efficiency have high levels of heat dissipation, which could be a limiting factor in particular design. In addition to the class of operation, the overall efficiency of a power amplifier is affected by factors such as dielectric and conductor losses. First quantify any loss in the circuit, then attempt to minimize it, and finally ensure that the mechanical and thermal design is adequate under all conditions.

Classes of Power Amplifiers

The main features of a large-signal amplifier are the circuit's power efficiency, the maximum amount of power that the circuit is capable of handling, and the impedance matching to the output device.

One method used to categorize amplifiers is by class. Basically, amplifier classes represent the amount the output signal varies over one cycle of operation for a full cycle of input signal.

Classes of Power Amplifiers

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Amplifier Efficiency

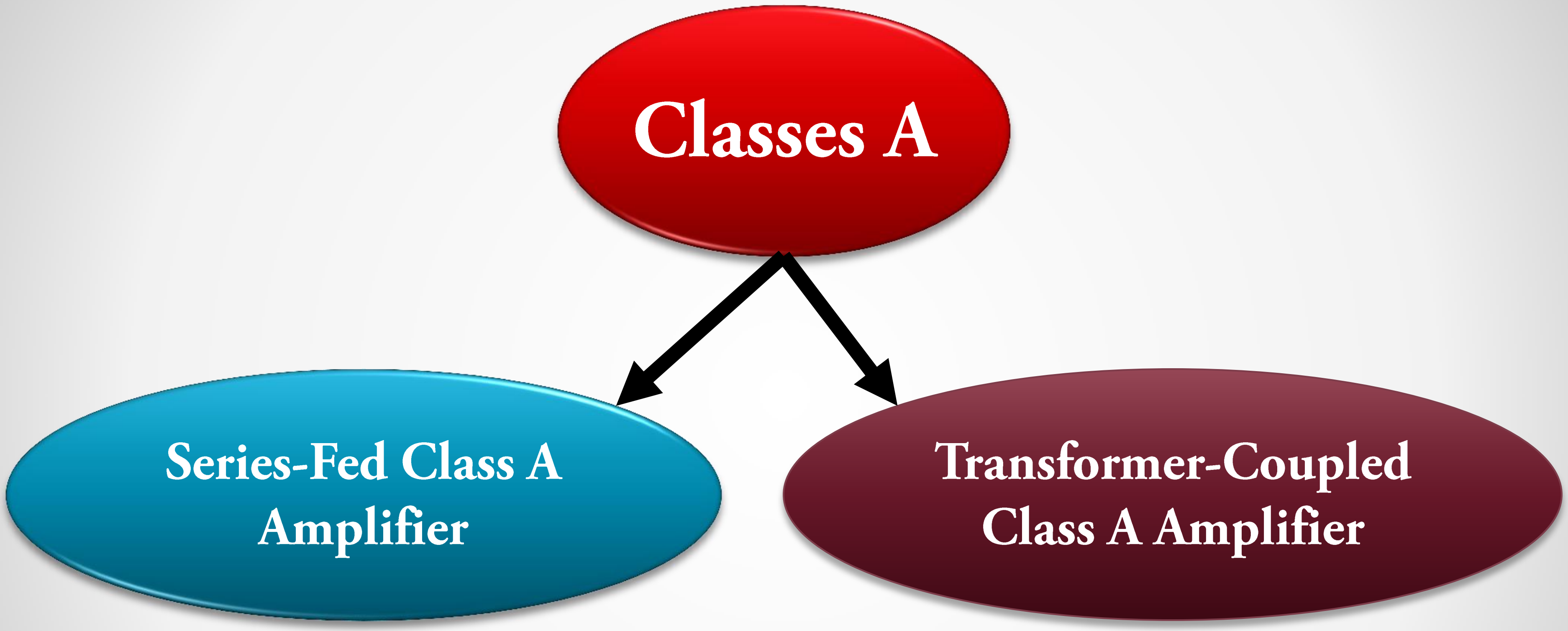
The power efficiency of an amplifier, defined as the ratio of power output to power input, improves (gets higher) going from class A to class D.

Classes of Power Amplifiers

Table 4.1 Comparison between the amplifier classes

	A	AB	B	C	D
Operating Cycle	**360°**	**180° to 360°**	**180°**	**Less than 180°**	**Pulse operation**
Power Efficiency	**25% to 50%**	**Between 25% and 78.5%**	**78.5%**		**Typically over 90%**

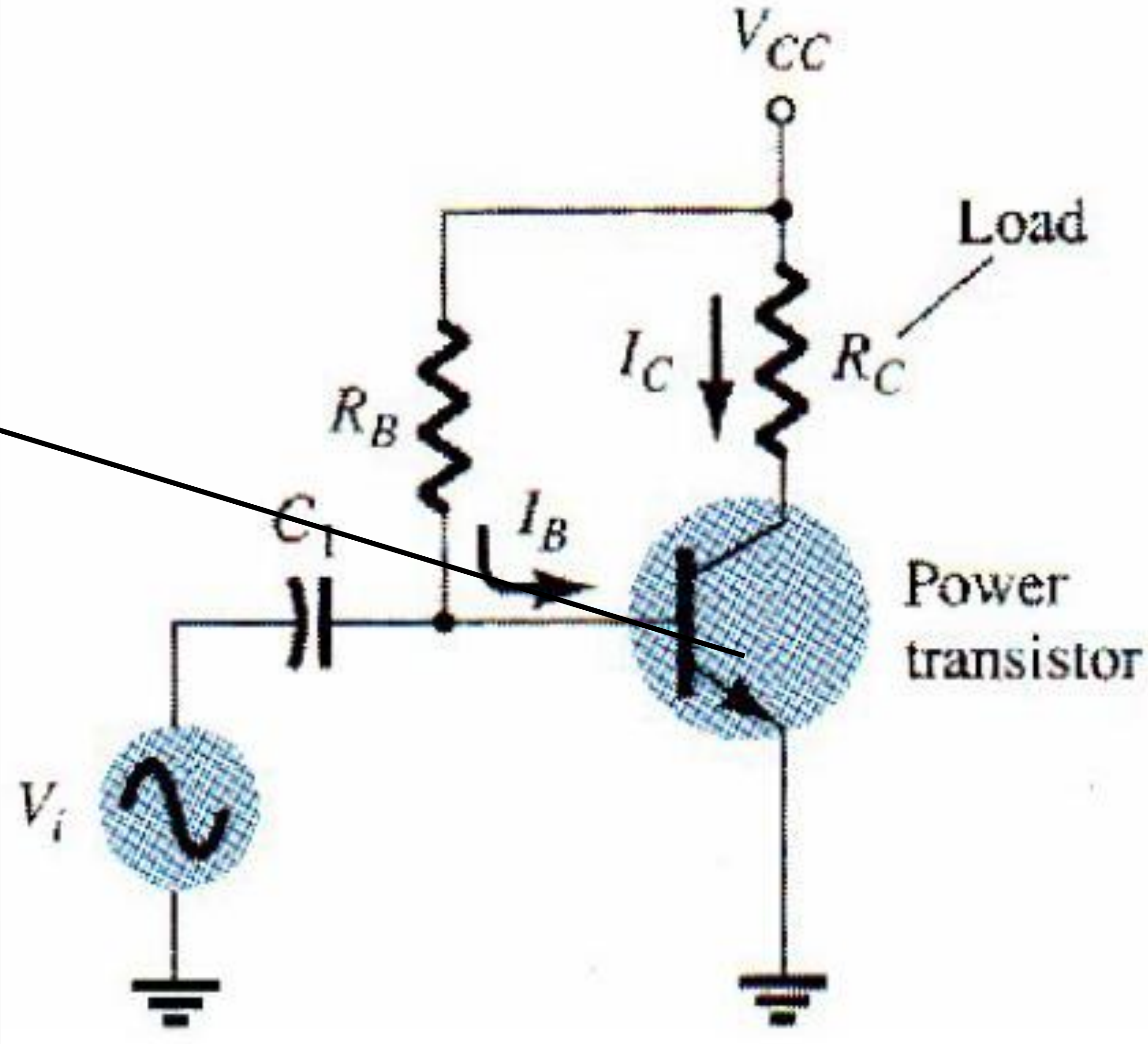
Class C is usually not used for delivering large amounts of power, and thus the efficiency is not given here.


Classes A
Series-Fed Class A Amplifier
Transformer-Coupled Class A Amplifier

Series-Fed Class A Amplifier

capable of operating in the range of a few to tens of watts.

The beta of a power transistor is generally less than 100



Series-Fed
Class A Amplifier

The overall amplifier circuit using power transistors that are capable of handling large power or current while not providing much voltage gain.

DC Bias Operation

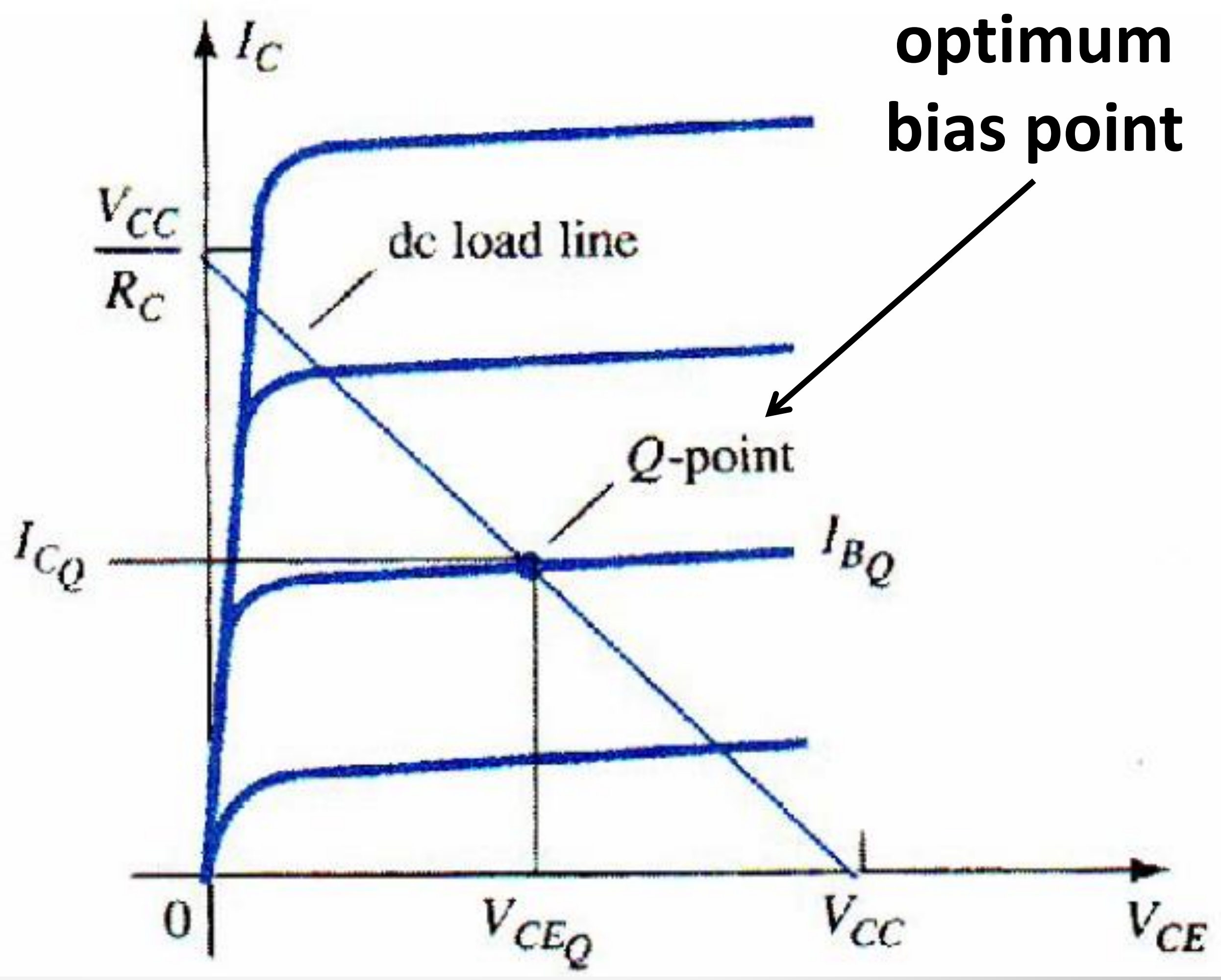
$$I_B = \frac{V_{CC} - 0.7}{R_B}$$

$$I_C = \beta I_B$$

$$V_{CE} = V_{CC} - I_C R_C$$

Series-Fed
Class A Amplifier

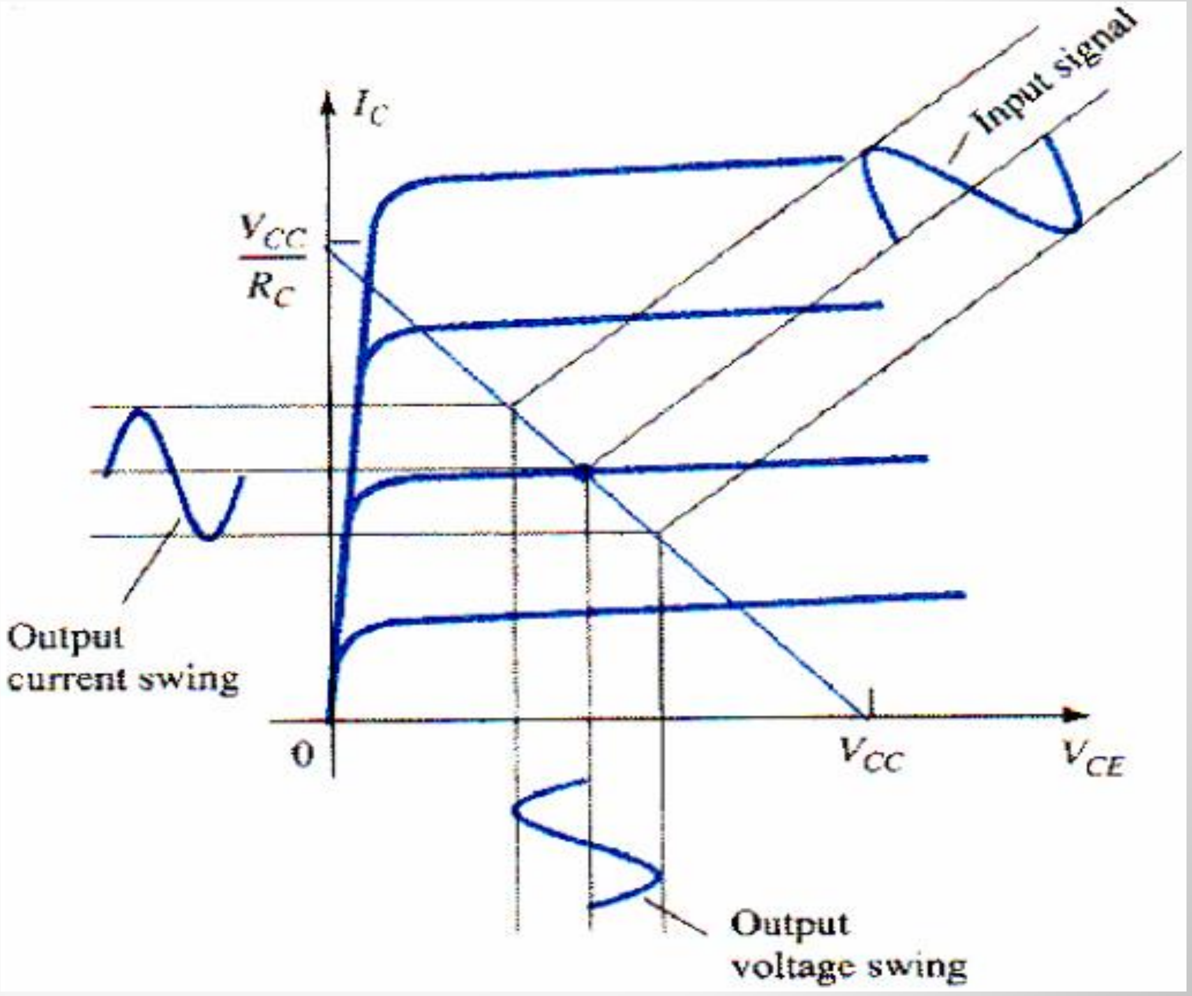
Figure 4.3
Transistor characteristic showing load line and Q-point (quiescent)



Series-Fed
Class A Amplifier

AC Operation

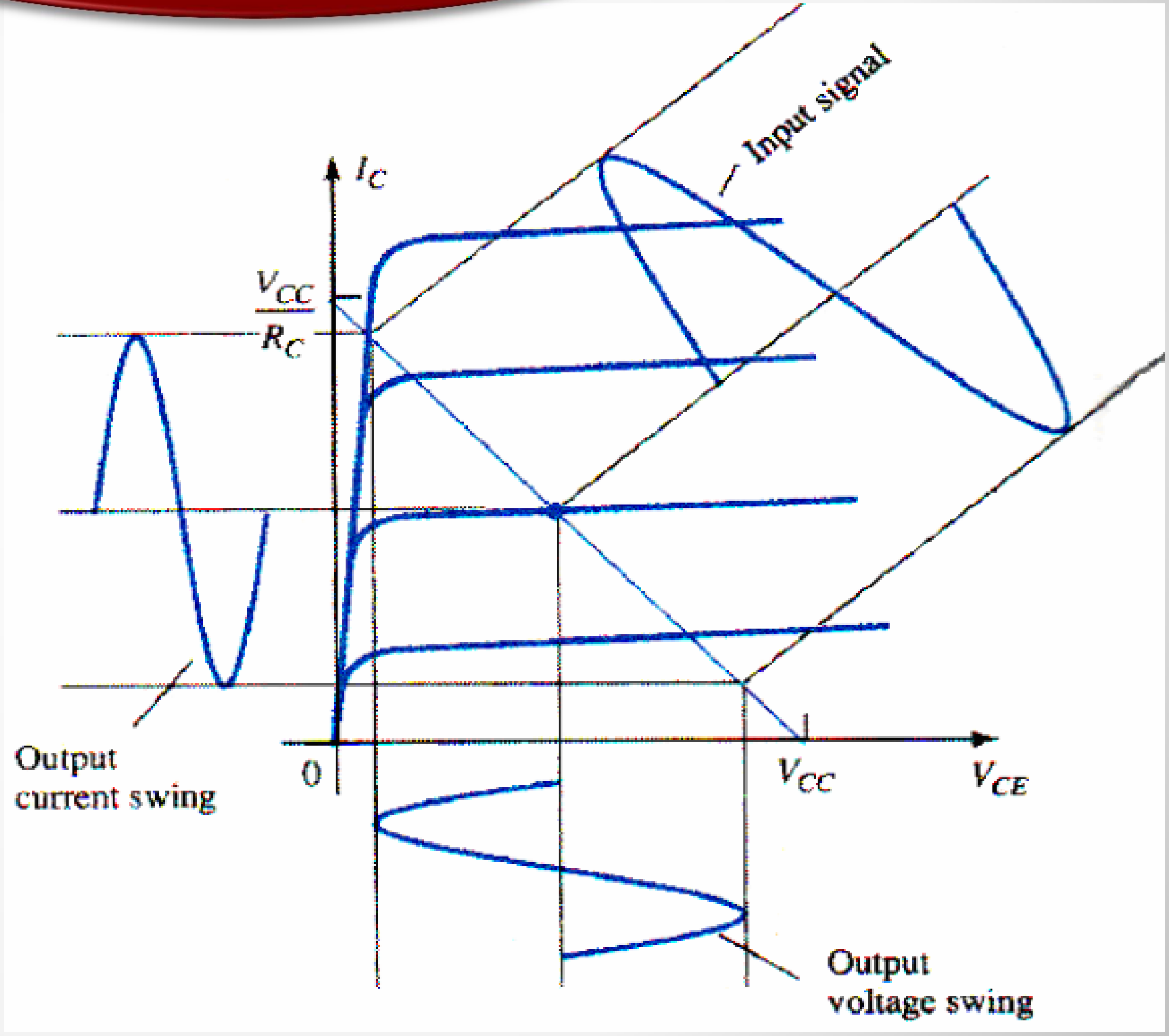
small input signal



Series-Fed Class A Amplifier

AC Operation

large input signal



Series-Fed Class A Amplifier

Power Consideration

With no input signal, the dc current drawn is the collector bias current, I_{CQ}. The power then drawn from the supply is

$$P_i(dc) = V_{CC} I_{CQ}$$

Even with an ac signal applied, the average current drawn from the supply remains the same

Series-Fed Class A Amplifier

Output Power

Using RMS signals

$$P_o(ac) = V_{CE}(rms)\, I_C(rms)$$

$$P_o(ac) = I_C^2(rms)\, R_C$$

$$P_o(ac) = \frac{V_{CE}^2(rms)}{R_C}$$

Series-Fed
Class A Amplifier

Output Power

Using peak signals

$$P_o(ac) = \frac{V_{CE}(p)\, I_C(p)}{2}$$

$$P_o(ac) = \frac{I_C^2(p)\, R_C}{2}$$

$$P_o(ac) = \frac{V_{CE}^2(p)}{2R_C}$$

Series-Fed Class A Amplifier

Using peak to peak signals

Output Power

$$P_o(ac) = \frac{V_{CE}(p-p)\, I_C(p-p)}{8}$$

$$P_o(ac) = \frac{I_C^2(p-p)\, R_C}{8}$$

$$P_o(ac) = \frac{V_{CE}^2(p-p)}{8R_C}$$

Series-Fed
Class A Amplifier

Efficiency

$$\%\eta = \frac{P_o(ac)}{P_i(dc)}\ x\ 100\%$$

Maximum Efficiency

If

$$V_{CE}(p-p) = V_{CC}$$

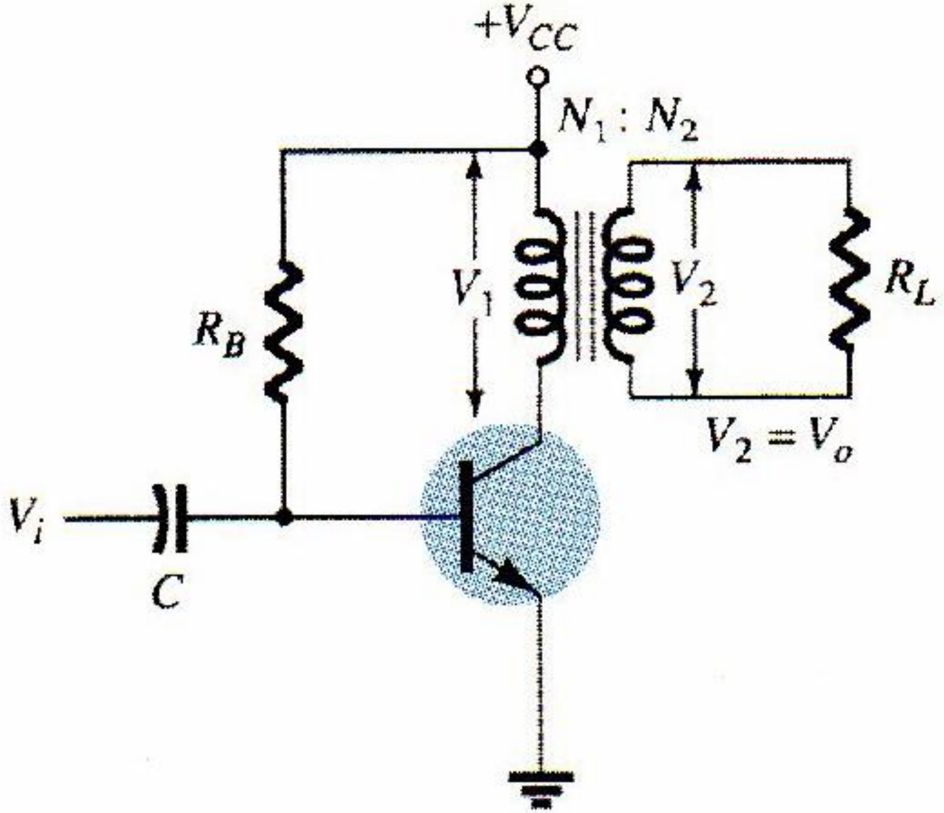
$$I_C(p-p) = \frac{V_{CC}}{R_C}$$

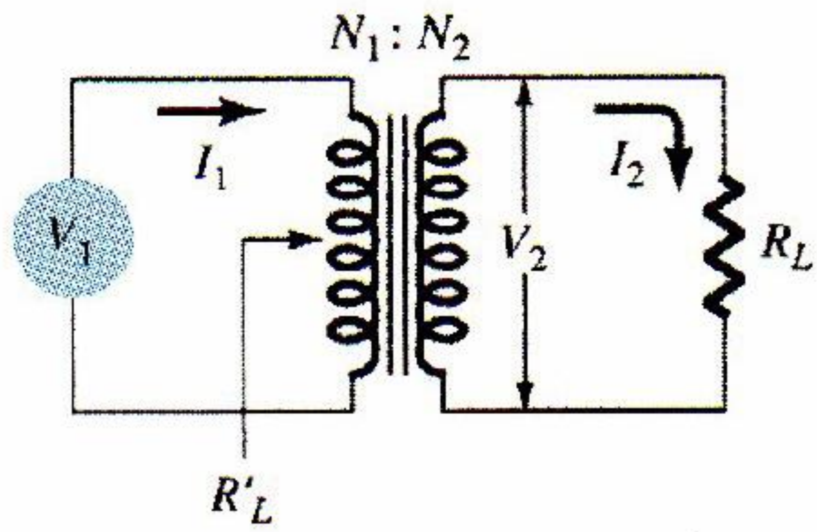
$$maximum\ P_o(ac) = \frac{V_{CC}\ (V_{CC}/R_C)}{8} = \frac{V_{CC}^2}{8R_C}$$

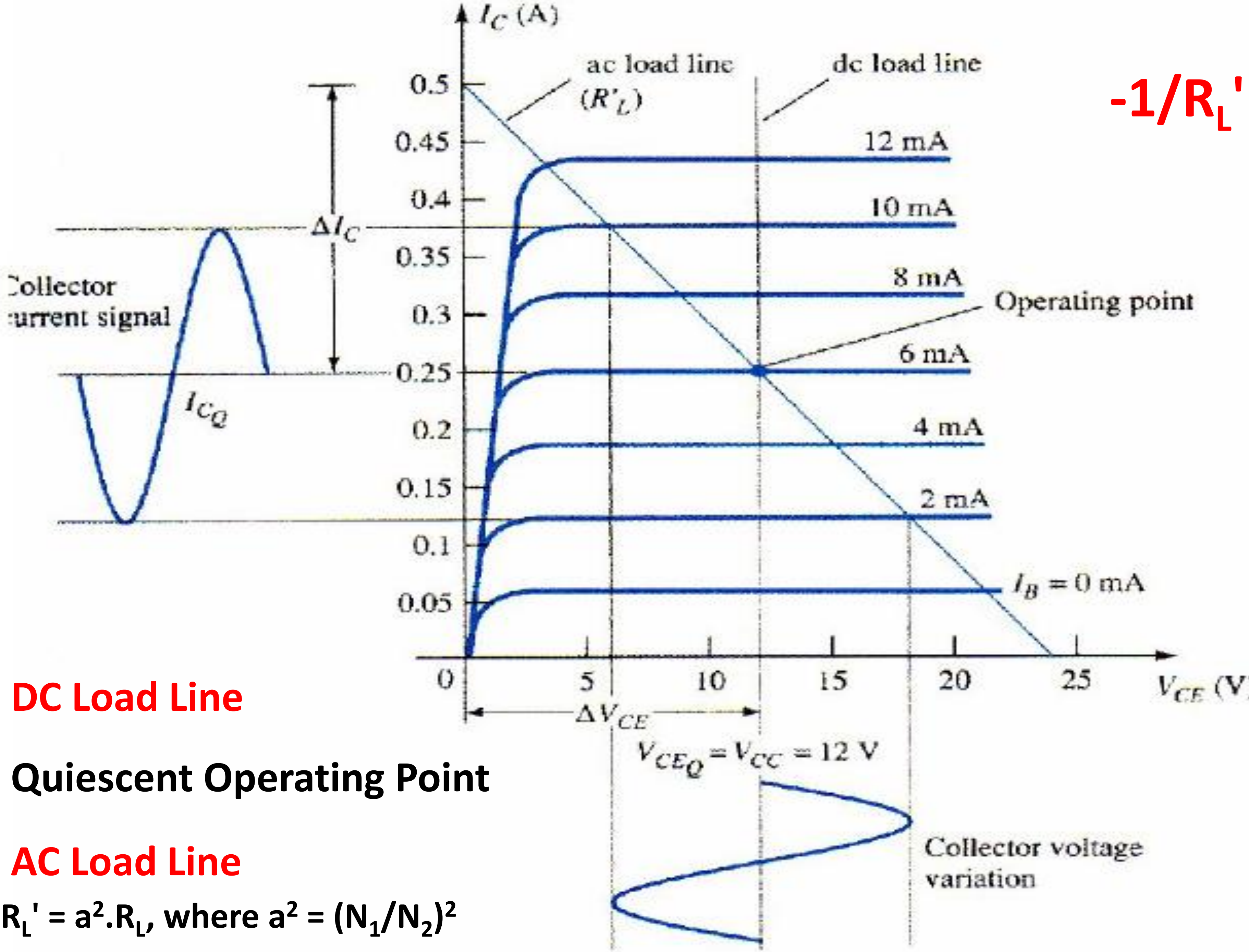
$$maximum\ P_i(dc) = V_{CC}(maximum\ I_C) = \frac{V_{CC}\ (V_{CC}/R_C)}{2} = \frac{V_{CC}^2}{2R_C}$$

$$maximum\ \%\eta = \frac{maximum\ P_o(ac)}{maximum\ P_i(dc)}\ x\ 100\% = \frac{V_{CC}^2/8R_C}{V_{CC}^2/2R_C}\ x\ 100\% = 25\%$$

Transformer-Coupled Class A Amplifier







$-1/R_L'$

DC Load Line

Quiescent Operating Point

AC Load Line

$R_L' = a^2.R_L$, where $a^2 = (N_1/N_2)^2$

Transformer-Coupled Class A Amplifier

Output AC Power

$$P_o(ac) = \frac{(V_{CE\,max} - V_{CE\,min})(I_{C\,max} - I_{C\,min})}{8}$$

For the ideal transformer, the voltage delivered to the load can be calculated using ($V_2 / V_1 = N_2 / N_1$). So the power across the load can then be expressed as:

$$P_L = \frac{V_L^2(rms)}{R_L}$$

where $V_L = V_2$

Transformer-Coupled Class A Amplifier

Efficiency

$$P_i\,(dc) = V_{CC}\, I_{CQ}$$

the power dissipated as heat

$$P_Q = P_i\,(dc) - P_o\,(ac)$$

Maximum Theoretical Efficiency

$$\%\,\eta = 50\left(\frac{V_{CE\,max} - V_{CE\,min}}{V_{CE\,max} + V_{CE\,min}}\right)^2 \%$$

THANK YOU

Dr. Mohamed Salah